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Post-dispersal weed seed predation by invertebrates in conventional and low-external-input crop rotation systems

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Abstract

Invertebrate seed predator communities were compared between conventionally managed maize/soybean and low-input maize/soybean/triticale–alfalfa/alfalfa crop rotation systems using pitfall traps from July to October 2003 and 2004. Predation of giant foxtail (*Setaria faberi*) seeds was investigated in conjunction with pitfall trap measurements during 2004. Crop identity, rather than management practices within a specific crop, had the greatest influence on the activity-density of invertebrate seed predators. *Gryllus pennsylvanicus* (Orthoptera: Gryllidae), the most abundant invertebrate seed predator, was trapped more often in maize than soybean and least often in triticale–alfalfa and alfalfa treatments. Predation of *S. faberi* seeds by invertebrates was higher in maize and soybean compared to triticale–alfalfa and alfalfa and there were higher predation rates in reduced input compared to conventionally managed soybean. Invertebrates consumed less than 30% of seeds in July, early August and early October, but as much as 80–90% of seeds in late August and September in maize and soybean. The percentage of *S. faberi* seeds consumed by invertebrates compared to all seed predators increased in late summer and was significantly higher in maize and soybean compared to triticale–alfalfa and alfalfa treatments. Regression analysis indicated that *G. pennsylvanicus* and *Allonemobius allardi* (Orthoptera: Gryllidae) activity-densities were significant predictors of *S. faberi* seed predation and explained 66% of the variation in seed removal.

Keywords: Agro-ecology; Crickets; Ground beetles; Iowa; Natural enemies; Biological weed control; Post-dispersal seed predation

1. Introduction

Seed predation has been studied extensively in natural systems and can significantly affect seed survival, spatial distributions of plant species, and plant community composition (Crawley, 2000). More recently, there has also been increasing attention focused on post-dispersal seed predation in agricultural habitats (Gallandt et al., 2005; Menalled et al., 2005). Indeed, some population dynamics models indicate that post-dispersal seed predation may be the most sensitive parameter affecting population growth rates of agricultural weeds (Davis et al., 2003).

Vertebrates such as birds (Holmes and Froud-Williams, 2005) and mice (Getz and Brighty, 1986), and invertebrates including crickets (Brust and House, 1988; Carmona et al., 1999), beetles (Tooley and Brust, 2002; Honek et al., 2003), ants (Diaz, 1992) and slugs (Cardina et al., 1996) have been reported to be important seed predators in arable farming systems. However, while there is some controversy as to the relative importance of vertebrates compared to invertebrates as agricultural weed seed predators (Marino et al., 1997; Westerman et al., 2003a), many studies have pointed to invertebrates as consuming the majority of agricultural weed seeds (Brust and House, 1988; Cromar et al., 1999; Gallandt et al., 2005). Indeed, Honek et al. (2003) estimated that carabid beetles in winter rape crops in the Czech Republic could consume between 1150–4000 weed seeds m^{-2} day^{-1}.

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The feeding behaviors of invertebrates indicate that they may play important roles in agricultural weed seed predation. Compared to vertebrates, invertebrates may be more efficient consumers of small weeds seeds (Brust and House, 1988). Studies by Westerman et al. (2003a) and Harrison et al. (2003) also indicate that invertebrate post-dispersal seed predation appears to be synchronized with weed seed shed in autumn, facilitating seed consumption before autumn or spring tillage can bury seeds beyond the reach of predators. There is also evidence that invertebrate seed predation is not dependent on distance from field margins (Westerman et al., 2003a), suggesting that invertebrate seed predation can remain high within large agricultural fields.

Rates of invertebrate seed predation can be highly variable among fields (Westerman et al., 2003a) and differences in management may contribute to the variability. There is evidence that invertebrate seed predation varies among crops (Honek et al., 2003) and may be positively related to the degree of canopy cover (Gallandt et al., 2005). There is conflicting evidence concerning the effects of tillage on invertebrate seed predation with some studies showing no effects (Cardina et al., 1996), negative effects (Brust and House, 1988), or even variable effects depending on the specific type of tillage (Cromar et al., 1999). The effects of herbicides and fertilizers on invertebrate seed predators have not been thoroughly investigated. However, there is some evidence that they may adversely affect invertebrate seed predators and consequently predation rates (Hance, 2002).

In this study, it was hypothesized that invertebrate seed predator activity-density and predation rates would be higher in cropping systems with less soil disturbance, fewer chemical inputs, and increased durations of ground cover. To test this hypothesis, invertebrate seed predator activity-density and weed seed predation rates in a conventional, 2-year maize/soybean cropping system were compared with those in a low-input, 4-year maize/soybean/triticale–alfalfa/alfalfa cropping system. The proportion of seed predation attributable to invertebrates throughout the growing season was also investigated using vertebrate exclosure and full exposure treatments. Laboratory feeding trials were conducted to determine the propensity of invertebrate species commonly encountered in Iowa agricultural fields to consume various weed seeds and to assess how the presence of invertebrate prey might affect weed seed predation.

2. Materials and methods

Crop rotations were established in 2002 on Clarion–Nicollet–Webster mixed loam soils at Iowa State University's Marsden Farm in Boone Co., Iowa, USA. The two cropping systems compared were a 2-year maize (*Zea mays* L.)/soybean (*Glycine max* (L.) Merr.) rotation and a 4-year maize/soybean/triticale (× *Triticosecale* Wittmack) underseeded with alfalfa (*Medicago sativa* L.)/alfalfa rotation. Prior to the cropping systems experiment, the land had been conventionally managed for maize and soybean production and was planted to oat in 2001. The experiment was laid out as a randomized complete block design with each phase of each rotation system present every year in each block. There were four replicate blocks separated by approximately 15 m of mowed, mixed grasses (mostly *Festuca arundinacea* Shreb.) and each treatment plot within the four blocks measured 18 × 84 m.

All maize plots were field cultivated immediately prior to planting in late April. Maize plots in the 4-year rotation were also moldboard ploughed the previous November to incorporate alfalfa residue from the previous phase of the rotation. Fertilizer nitrogen was applied to the 2-year rotation maize at a rate of 150 and 110 kg N ha^{-1} yr^{-1} in 2003 and 2004, respectively. Maize in the 4-year rotation received fertilizer nitrogen at a rate of 55 and 70 kg N ha^{-1} yr^{-1} in 2003 and 2004, respectively, and received organic N inputs in the form of composted manure applied at a rate of 15 Mg ha^{-1} yr^{-1} (fresh weight). Weeds were chemically controlled in the 2-year maize plots with pre-plant incorporated (PPI) metolachlor and isoxaflutole in 2003 and pre-emergence (PRE) applications of metolachlor and isoxaflutole in 2004 at 1.60 and 0.11 kg a.i. ha^{-1}, respectively, in both years. Post-emergence (POST), broadcast applications of nicosulfuron, rimsulfuron, and mesotrione, at 0.026, 0.013, and 0.07 kg a.i. ha^{-1}, respectively, were also made to 2-year maize plots in 2003. PPI herbicides were not applied to the 4-year maize plots, but POST, banded applications of nicosulfuron, rimsulfuron, and mesotrione at 0.013, 0.007, and 0.035 kg a.i. ha^{-1} were made in both 2003 and 2004 (materials were applied to only 50% of surface area; reported values indicate dosages to total plot area). In the 2-year maize, weeds were rotary hoed once in 2003, but no mechanical weed control was used in 2004. Mechanical weed control was relied on more heavily in the 4-year maize with one rotary hoeing and two interrow cultivations in 2003, and one rotary hoeing and one interrow cultivation in 2004.

Soybean was planted in late May immediately following field cultivation. Both 2-year and 4-year soybean plots were chisel ploughed the previous November and cultivated in April to incorporate maize residue. No fertilizer additions were made to soybean treatments. Weeds were controlled in the 2-year soybean in 2003 with PPI metolachlor and in 2004 with PRE metolachlor applied at 1.60 kg a.i. ha^{-1} both years. In 2003, 2-year soybean plots were also treated with POST broadcast bentazon, flumiclorac, and clethodim applied at 1.12, 0.06, and 0.18 kg a.i. ha^{-1}, respectively. In 2004, 2-year soybean plots were also treated with POST broadcast bentazon and clethodim applied at 1.12 and 0.11 kg a.i. ha^{-1}, respectively. Chemical weed control in the 4-year soybean included PPI metolachlor in 2003 and PRE metolachlor in 2004 applied at 1.60 kg a.i. ha^{-1} in both years. The 4-year soybean plots were also treated with POST